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WEAR-RESISTANT LAYER

The invention relates to a wear-resistant layer which is applied to a surface, which is to be protected, of a component which is subjected to mechanical and/or fluidic loads and substantially comprises amorphous or amorphous-nanocrystalline metals.

Components which are subjected to mechanical stresses from friction or around which media flow are generally subject to abrasive or erosive wear. In the field of internal-combustion engines, this wear occurs, for example in the case of piston engines, on valves, pistons or the like. In the field of gas turbines, furthermore, the components around which media flow need to be protected against erosion and corrosion.

It is known from the journal Metall, volume 36 (August 1982), pages 841 to 853, to weld amorphous metal strips, on account of their good corrosion resistance and their high hardness and resistance to abrasion, to turbine blades of aircraft engines; amorphous iron-base metals and the production of the metal strips using continuous quenching methods are proposed for this purpose.

De 38 00 454 A1 has disclosed a process for the production of corrosion-resistant and wear-resistant layers and shaped bodies made from metallic, amorphous materials, in which first of all an amorphous powder which can be processed further by powder metallurgy is produced from metallic alloys, and this powder is then applied to the substrate, for example by plasma spraying.

DE 38 14 444 A1 has disclosed amorphous alloys which are highly resistant to corrosion and substantially comprise at least one element selected from the group consisting of Ta and Nb and in addition may have at least one element selected from the group consisting of Ti and Zr, with Cu also always being a constituent. Numerous Cu-base alloys made from these elements are disclosed, and these alloys are applied to a substrate by spray deposition.

DE 42 16 150 A1 discloses highly corrosion-resistant amorphous alloys based on Ti or Zr and Cr, which are said to have a high

resistance to corrosion and wear and are applied to a substrate by sputtering or atomization.

DE 689 03 073 T2 has disclosed a thin, corrosion-resistant and heat-resistant film made from an aluminium alloy and a process for its production, in which the alloy contains, as further elements, Ni, Zr or Y and is applied by thin-film formation techniques, such as cathode sputtering, vacuum deposition or ion plating, to a substrate, such as for example a wire or a filament.

US 5,389,226 has disclosed the electrodeposition of an amorphous, microcrystalline (including nanocrystalline) Ni-W alloy on a substrate, such as a part of an internal-combustion engine, the coating having a high hardness and being able to withstand wear and corrosion.

JP 10096077 A has disclosed a gradient coating with a thickness of over 0.1 mm which is produced from an Al alloy, an element selected from the group consisting of Cr, Mn, Fe, Co, Ni, Cu, Ti, Zr and Y, rare earths and a misch metal by electron beam deposition on a substrate, the hardness of the coating being varied by means of the ratio between Al and the element from the said group.

Chemical Abstracts XP002136889 has disclosed the coating of a copper wire, which has a first, amorphous layer of an Ni-P alloy, with an amorphous Pd-Cu-Si alloy by means of a laser, by means of which electrical contact elements are said to become better able to withstand dissolution and abrasion.

The problem on which the invention is based consists in providing a wear-resistant layer of the generic type described in the introduction, which protects component surfaces which are acted on mechanically, for example by friction, or fluidically against wear and increases the service life of these components. Suitable alloys are to be provided for this purpose.

According to the invention, the solution to this problem is characterized in that the layer comprises an alloy based on Cu-Al-Ti (or -Ta or -Zr) or Pt-Al-Si or Ta-Si-N, at least one rare earth and a transition metal, such as Cu or Ni or Co.

The advantage of wear-resistant layers of this type is that their alloys, unlike conventional crystalline metals, on account of their amorphous or vitreous structure, do not have any grain boundaries and therefore on the one hand have a high resistance to abrasive or erosive wear and on the other hand have a high elastic restoring capacity.

In a configuration which does not form part of the invention, the layer substantially comprises an Ni-W-base alloy, in which case the alloy may be Ni-rich and contain only between 20 and 40 atomic % of W. To achieve the amorphous or amorphous and nanocrystalline metal structure, the alloy may inexpensively be electrodeposited on the surface of the component to be coated. An alloy of this type which is present in the form of amorphous or amorphous-nanocrystalline metal has a high hardness, in particular on account of the element W, and is extremely wear-resistant and temperature-resistant.

In an alternative configuration, the wear-resistant layer may substantially comprise an alloy based on Cu-Al-Ti (or -Ta or -Zr) or Pt-Al-Si or Ta-Si-N, in which case the layer can be applied to the surface of the component by means of PVD (physical vapour deposition) processes, and in particular Ta-Si-N is suitable for applications at elevated temperatures.

In an embodiment which does not form part of the invention, the wear-resistant layer may substantially comprise an alloy based on Zr-Ti, in which case the amorphous or amorphous and nanocrystalline metal structure is produced by applying the alloy from the melt.

Alternatively, in an embodiment which does not form part of the invention, the wear-resistant layer may substantially comprise an alloy based on Fe-Cr-B, in which case the alloy is preferably iron-rich and contains approximately 70 atomic % of Fe. A wear-resistant layer of this type may be applied to the surface of the component by, for example, thermal spraying processes.

In a further configuration which does not form part of the invention, the wear-resistant layer may substantially comprise an alloy of Al, at least one rare earth and a transition metal, such as for example Cu or Ni or Co.

The layer is preferably applied to the root of a blade of a gas turbine to protect against fretting, since in that region, while the gas turbine is operating, a high level of frictional wear with high-frequency alternating loads with low amplitudes occurs.

In another configuration, the wear-resistant layer may be applied to a component which substantially comprises fibre-reinforced plastic (FRP), in order to protect this component against erosion. In the case of FRP blades for compressors of gas turbines, examples of known means for protecting against erosion are metallic foils, felts, wire meshes or coating materials, which have drawbacks in terms of the manufacturing costs or the required service life and are not yet usable.

In an alternative exemplary embodiment, the wear-resistant layer may be applied to a rotor carrier or rotor ring, which is designed as a disc or a ring, of an integrally bladed FRP rotor of a gas turbine, as protection against abrasive and/or erosive wear.

In an alternative use, the wear-resistant layer is applied to a component of a reciprocating engine, such as for example a valve, a camshaft, a crankshaft, a piston ring or a piston pin.

Further configurations of the invention are described in the subclaims.

In the text which follows, the invention is explained in more detail on the basis of exemplary embodiments and with reference to a drawing, in which:

Fig. 1 diagrammatically depicts the structure of an amorphous metal,

Fig. 2 diagrammatically depicts the structure of an amorphous and nanocrystalline or partially crystalline metal,

Fig. 3 shows a diagrammatic and perspective view of an FRP blade with an exemplary embodiment of the wear-resistant layer according to the invention,

Fig. 4 shows a diagrammatic and perspective view of a metallic blade with an alternative exemplary embodiment of the wear-resistant layer according to the invention, and

Fig. 5 shows a diagrammatic and perspective view of an FRP rotor with a further alternative exemplary embodiment of the wear-resistant layer according to the invention.

Fig. 1 diagrammatically depicts the microstructure of an amorphous metal, in which the elements are not, as is the case with Ti, for example, arranged in a fixed, crystalline structure, but rather are arranged randomly without a regular crystal lattice (region 1). The grain boundaries which are absent as a result lead to amorphous or amorphous and nanocrystalline metals having a high resistance to wear and a high Vickers hardness. Moreover, unlike with the crystalline metals, there is no embrittlement and strain hardening.

Fig. 2 diagrammatically depicts the structure of an amorphous and nanocrystalline or partially crystalline metal, in which the elements are in part arranged randomly in an amorphous structure (region 1) and in part are in the form of relatively small regions with a crystalline structure (region 2). Amorphous and nanocrystalline or partially crystalline metals of this type also have a high resistance to abrasive or erosive wear and have a high Vickers hardness.

Fig. 3 shows a diagrammatic and perspective view of a blade of a gas turbine which is denoted overall by 3 and in which a blade 4 consists of fibre-reinforced plastic and is attached to a metallic blade root 5 consisting of a Ti-base alloy. A blade 3 of this type is used, for example, in a compressor and its blade root 5 is attached to a rotor ring or rotor carrier releasably or alternatively integrally using a suitable welding process. The fact that the blade 4 is formed from fibre-reinforced plastic has proven advantageous with a view to reducing weight. However, drawbacks include the material's generally inadequate wear resistance to erosion. For this reason, the blade 4 made from fibre-reinforced plastic is completely provided with a wear-resistant layer 6, which substantially comprises amorphous or amorphous and nanocrystalline metals.

In the present configuration, an alloy which substantially comprises Ni-W, is Ni-rich and contains approximately 30 atomic % of W is selected. To form the amorphous or amorphous and nanocrystalline structure, the alloy is applied to the surface of the blade 4 made from carbon fibre-reinforced plastic by electrodeposition. The mechanical properties and the wear resistance of the wear-resistant layer 6 can be set using the parameters temperature, voltage and chemistry of the electrodeposition bath. In particular, the hardness of the wear-resistant layer 6 can also be increased by a final heat treatment at temperatures between approximately 100°C and 500°C. Alternatively, it is also possible for only individual sections of the blade 3, such as the leading edge or the blade tip, to be provided with the wear-resistant layer 6. This layer could also consist of an alloy based on Cu-Al-Ti (or -Ta or -Zr) or Pd-Cu-Si or Pt-Al-Si or Pa-Si-N, since these alloys, in particular in combination with their amorphous or amorphous-nanocrystalline metal structure, are wear-resistant, hard and temperature-resistant.

Fig. 4 shows a metallic (rotor) blade 7 of a compressor of a gas turbine which has a blade root 8 with a fir-tree profile 9 for releasable attachment to a rotor. The blade is produced by powder metallurgy from Ti-Al. Alternatively, the wear-resistant layer 6 could also be applied to cast or forged blades or other components of a gas turbine. While the gas turbine is operating, fretting often occurs at the root 8 of the blade 7. To avoid the resultant wear and therefore to increase the service life, the blade 7 is protected at its root 8 and in particular in the region of the fir-tree profile 9 with a wear-resistant layer 6 which substantially comprises amorphous or amorphous-nanocrystalline metals. The wear-resistant layer 6 substantially comprises an alloy based on Pd-Cu-Si and is applied to that surface of the blade root 8 which is to be protected against fretting by a PVD process. In addition to its good mechanical properties, a wear-resistant layer 6 of this type is also distinguished by a good resistance to oxidation. For applications at elevated temperatures, the wear-resistant layer 6 may alternatively consist of an alloy based on Ta-Si-N.

In the present application shown in Fig. 4, as an alternative a wear-resistant layer 6 comprising amorphous or amorphous-nanocrystalline metals and made from an alloy based on Fe-Cr-B is

also suitable, this layer being iron-rich and containing approximately 70 atomic % of Fe. The desired structure of this alloy, which is amorphous at least in regions, can be established during application by thermal spraying.

Fig. 5 shows an integrally bladed rotor 10 of a gas turbine, to the circumferential surface 11 of which a plurality of blades 12, which are generally arranged equidistantly and extend substantially in the radial direction, are attached. A rotor 10 of this type is produced, for example, integrally from carbon fibre-reinforced plastic and has a poor resistance to wear. To improve the resistance to abrasive and erosive wear during operation, the rotor 10 is provided with a wear-resistant layer 6 made from an Ni-W-base alloy, which is Ni-rich, contains approximately 35 atomic % of W and, to form the amorphous or amorphous-nanocrystalline structure, is produced on the surface of the rotor 10 by electrodeposition.

Alternatively, the rotor 10 may, at the abovementioned regions, be coated with a layer 6 of an alloy of Al, at least one rare earth and a transition metal, such as Cu or Ni or Co, since these alloys, in combination with their amorphous or amorphous-nanocrystalline metal structure, are wear-resistant and temperature-resistant.